

# Storypoint Prediction - jirasoftware

September 14, 2024

## 1 Storypoint Prediction: Regression Approach

### 1.1 Preparation

```
[1]: import os
import json
import random

import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import seaborn as sns
from scipy.sparse import csr_matrix, hstack, vstack

from sklearn.pipeline import Pipeline
from sklearn.preprocessing import RobustScaler
from sklearn.metrics import mean_squared_error, r2_score, mean_absolute_error, f1_score, precision_score, recall_score, accuracy_score
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.model_selection import learning_curve, validation_curve
from trainer import GridSearchCVTrainer

# ['appceleratorstudio', 'aptanastudio', 'bamboo', 'clover',
#  'datamanagement', 'duracloud', 'jirasoftware', 'mesos',
#  'moodle', 'mule', 'mulestudio', 'springxd',
#  'talenddataquality', 'talendesb', 'titanium', 'usergrid']
project_name = 'jirasoftware'
```

#### 1.1.1 Plot learning curve

```
[2]: def plot_learning_curve(estimator, title, X, y, ylim=None, cv=None,
                             n_jobs=-1, train_sizes=np.linspace(.1, 1.0, 10)):
    plt.figure()          # Create new figure
    plt.title(title)      # Set title of the figure

    # Set y-axis limits: ylim=(min, max)
    if ylim is not None:
        plt.ylim(*ylim)
```

```

plt.xlabel("Training examples") # Set x-axis label
plt.ylabel("Score")             # Set y-axis label

# Generate learning curve data
train_sizes, train_scores, test_scores = learning_curve(
    estimator, X, y, cv=cv, n_jobs=n_jobs, train_sizes=train_sizes,
    ↪scoring='neg_mean_squared_error')

train_scores_mean = np.mean(train_scores, axis=1) # Calculate mean of
↪training scores
train_scores_std = np.std(train_scores, axis=1)   # Calculate standard
↪deviation of training scores
test_scores_mean = np.mean(test_scores, axis=1)   # Calculate mean of test
↪scores
test_scores_std = np.std(test_scores, axis=1)      # Calculate standard
↪deviation of test scores

plt.grid() # Display grid

# Fill the area between the mean training score and the mean +/- std
↪training score
plt.fill_between(train_sizes, train_scores_mean - train_scores_std,
                 train_scores_mean + train_scores_std, alpha=0.1,
                 color="r")

# Fill the area between the mean test score and the mean +/- std test score
plt.fill_between(train_sizes, test_scores_mean - test_scores_std,
                 test_scores_mean + test_scores_std, alpha=0.1, color="g")

# Plot mean training score as points
plt.plot(train_sizes, train_scores_mean, 'o-', color="r",
         label="Training score")
# Plot mean test score as points
plt.plot(train_sizes, test_scores_mean, 'o-', color="g",
         label="Validation score")

plt.legend(loc="best") # Display legend
return plt

```

### 1.1.2 Plot validation curve

```

[3]: def plot_validation_curve(estimator, title, X, y, param_name, param_range,
                             y_lim=None, cv=10, n_jobs=-1):
    train_scores, val_scores = validation_curve(estimator=estimator, X=X, y=y,
                                                param_name=param_name,
    ↪param_range=param_range,

```

```

cv=cv, n_jobs=n_jobs,
    ↪
    ↪scoring='neg_mean_squared_error')

    # Calculate mean and standard deviation of training and validation scores
    train_mean = np.mean(train_scores, axis=1)
    tran_std = np.std(train_scores, axis=1)
    val_mean = np.mean(val_scores, axis=1)
    val_std = np.std(val_scores, axis=1)
    print(val_mean)

    # Plot train scores
    plt.plot(param_range, train_mean, color='r', marker='o', markersize=5,
    ↪label='Training score')
    plt.fill_between(param_range, train_mean + tran_std, train_mean - tran_std,
    ↪alpha=0.15, color='r')

    # Plot validation scores
    plt.plot(param_range, val_mean, color='g', linestyle='--', marker='s',
    ↪markersize=5, label='Validation score')
    plt.fill_between(param_range, val_mean + val_std, val_mean - val_std,
    ↪alpha=0.15, color='g')

    plt.title(title)        # Set title of the plot
    plt.grid()              # Display grid
    plt.xscale('log')        # Set x-axis scale to log
    plt.legend(loc='best')   # Display legend
    plt.xlabel('Parameter') # Set x-axis label
    plt.ylabel('Score')      # Set y-axis label

    # Set y-axis limits
    if y_lim != None:
        plt.ylim(y_lim)

    return plt

```

### 1.1.3 Evaluate model

```

[4]: def evaluate_model(model, model_name, X_test, y_test, y_logscale=False,
    ↪save_directory=None):
    y_pred = model.predict(X_test)
    if(y_logscale):
        y_pred = np.exp(y_pred)

    lines = [model_name + '\s evaluation results:']

    mse = mean_squared_error(y_test, y_pred)

```

```

rmse = np.sqrt(mse)
mae = mean_absolute_error(y_test, y_pred)
r2 = r2_score(y_test, y_pred)

lines.append(f' - Mean squared error:      {mse:.4f}')
lines.append(f' - Root mean squared error: {rmse:.4f}')
lines.append(f' - Mean absolute error:     {mae:.4f}')
lines.append(f' - R2 error:                {r2:.4f}')

y_pred = np.round(y_pred).astype(int)
f1 = f1_score(y_test, y_pred, average='weighted')
precision = precision_score(y_test, y_pred, average='weighted',
↪zero_division=0)
recall = recall_score(y_test, y_pred, average='weighted', zero_division=0)
accuracy = accuracy_score(y_test, y_pred)

lines.append(f' - F1 score:                {f1:.4f}')
lines.append(f' - Precision:              {precision:.4f}')
lines.append(f' - Recall:                 {recall:.4f}')
lines.append(f' - Accuracy:               {accuracy:.4f}')
lines.append('-----')
lines.append('')

# Save to file

if(save_directory != None):
    filename = save_directory + project_name + '.txt'
    directory = os.path.dirname(filename)
    if not os.path.exists(directory):
        os.makedirs(directory)
    with open(filename, 'a') as f:
        for line in lines:
            print(line)
            f.write(line + '\n')
else:
    for line in lines:
        print(line)

```

#### 1.1.4 Set random seed

```

[5]: # Set random seed for numpy
np.random.seed(42)

# Set random seed for random
random.seed(42)

# Set random seed for os

```

```
os.environ['PYTHONHASHSEED'] = '42'
```

## 1.2 Dataset set-up

### 1.2.1 Bag of Words preprocessing

This is a Bag of Words preprocess approach. I will use 2 CountVectorizer from sklearn to change title and description to two 2 vectors and then concatenate them together. In the rest of this notebook, I will use cross-validation instead hold-out. Therefore, I will join the validation set with training set.

```
[6]: # # Import and remove NaN value

# data_train = pd.concat([pd.read_csv('data/' + project_name + '/' +
    ↪project_name + '_train.csv'),
#                          pd.read_csv('data/' + project_name + '/' +
    ↪project_name + '_valid.csv')])
# data_test = pd.read_csv('data/' + project_name + '/' + project_name + '_test.
    ↪csv')

# data_train['description'].replace(np.nan, '', inplace=True)
# data_test['description'].replace(np.nan, '', inplace=True)

# # Vectorize title
# title_vectorizer = CountVectorizer(ngram_range=(1, 2), min_df=2)
# title_vectorizer.fit(pd.concat([data_train['title'], data_test['title']]))

# # Vectorize description
# description_vectorizer = CountVectorizer(ngram_range=(1, 2), min_df=2)
# description_vectorizer.fit(pd.concat([data_train['description'],
    ↪data_test['description']]))

# X_train = hstack([title_vectorizer.transform(data_train['title']).
    ↪astype(float),
#                  description_vectorizer.transform(data_train['description']).
    ↪astype(float),
#                  data_train['title'].apply(lambda x : len(x)).to_numpy().
    ↪reshape(-1, 1),
#                  data_train['description'].apply(lambda x : len(x)).
    ↪to_numpy().reshape(-1, 1)
#                  ])

# y_train = data_train['storypoint'].to_numpy().astype(float)

# X_test = hstack([title_vectorizer.transform(data_test['title']).astype(float),
```

```
#             description_vectorizer.transform(data_test['description']).
↪astype(float),
#             data_test['title'].apply(lambda x : len(x)).to_numpy().
↪reshape(-1, 1),
#             data_test['description'].apply(lambda x : len(x)).
↪to_numpy().reshape(-1, 1)
#             ])

# y_test = data_test['storypoint'].to_numpy().astype(float)
```

```
[7]: # print('Check training dataset\'shape:', X_train.shape, y_train.shape)
# print('Check testing dataset\'shape:', X_test.shape, y_test.shape)
```

I will use log-scale the label to get a normal distribution of it.

```
[8]: # y_train_log = np.log(y_train)
```

### 1.2.2 doc2vec preprocessing

This process is already prepared so I only need to import the thing

```
[9]: data_train = pd.concat([pd.read_csv('doc2vec/' + project_name + '/' +
↪project_name + '_train.csv'),
                             pd.read_csv('doc2vec/' + project_name + '/' +
↪project_name + '_valid.csv')])
data_test = pd.read_csv('doc2vec/' + project_name + '/' + project_name + '_test.
↪csv')

X_train = np.vstack(data_train['doc2vec'].apply(lambda x: np.fromstring(x[1:
↪-1], sep=' ')).to_numpy())
y_train = data_train['storypoint'].to_numpy().astype(int)

X_test = np.vstack(data_test['doc2vec'].apply(lambda x: np.fromstring(x[1:-1],
↪sep=' ')).to_numpy())
y_test = data_test['storypoint'].to_numpy().astype(int)
```

Check shape of the datasets

```
[10]: print('Check training dataset\'shape:', X_train.shape, y_train.shape)
print('Check testing dataset\'shape:', X_test.shape, y_test.shape)
```

```
Check training dataset'shape: (258, 128) (258,)
Check testing dataset'shape: (28, 128) (28,)
```

```
[11]: y_train_log = np.log(y_train)
```

## 1.3 Model training

### 1.3.1 Linear Regressor

```
[12]: from sklearn.linear_model import ElasticNet, Ridge
```

Ridge

```
[13]: dict_param = {  
    'alpha': [.0001, .001, .01, .1, 1, 10, 100, 1000, 10000],  
    'random_state': [42]  
}
```

```
[14]: grid_search = GridSearchCVTrainer(name='Ridge', model=Ridge(),  
    ↪param_grid=dict_param,  
    cv=5, n_jobs=5, directory='settings/doc2vec/'  
    ↪+ project_name + '/')  
grid_search.load_if_exists()  
grid_search.fit(X_train, y_train_log)  
  
ridge_model = grid_search.best_estimator_  
ridge_model.fit(X_train, y_train_log)
```

0it [00:00, ?it/s]

```
[14]: Ridge(alpha=0.01, random_state=42)
```

```
[15]: evaluate_model(ridge_model, 'Ridge model', X_test, y_test, y_logscale=True,  
    ↪save_directory='results/doc2vec/')
```

Ridge model's evaluation results:

- Mean squared error:	7.1289
- Root mean squared error:	2.6700
- Mean absolute error:	1.9280
- R2 error:	0.0220
- F1 score:	0.0909
- Precision:	0.0667
- Recall:	0.1429
- Accuracy:	0.1429

-----

```
[16]: ridge_model.get_params()
```

```
[16]: {'alpha': 0.01,  
    'copy_X': True,  
    'fit_intercept': True,  
    'max_iter': None,  
    'positive': False,  
    'random_state': 42,
```

```
'solver': 'auto',
'tol': 0.0001}
```

Elastic net:

```
[17]: dict_param['l1_ratio'] = [.2, .4, .6, .8, 1]
      dict_param['max_iter'] = [5000]
```

```
[18]: grid_search = GridSearchCVTrainer(name='Elastic Net', model=ElasticNet(),
    ↪ param_grid=dict_param,
    cv=5, n_jobs=5, directory='settings/doc2vec/'
    ↪ + project_name + '/')
      grid_search.load_if_exists()
      grid_search.fit(X_train, y_train_log)

      elastic_model = grid_search.best_estimator_
      elastic_model.fit(X_train, y_train_log)
```

```
Out [00:00, ?it/s]
c:\Users\aupho\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\linear_model\_coordinate_descent.py:697: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 6.131e-02, tolerance: 1.210e-02
      model = cd_fast.enet_coordinate_descent(
```

```
[18]: ElasticNet(alpha=0.0001, l1_ratio=0.2, max_iter=100000, random_state=42)
```

```
[19]: evaluate_model(elastic_model, 'Elastic Net model', X_test, y_test,
    ↪ y_logscale=True, save_directory='results/doc2vec/')
```

Elastic Net model's evaluation results:

```
- Mean squared error:      7.2992
- Root mean squared error: 2.7017
- Mean absolute error:     1.9987
- R2 error:                -0.0013
- F1 score:                0.1045
- Precision:               0.0793
- Recall:                  0.1786
- Accuracy:                0.1786
```

-----

```
[20]: elastic_model.get_params()
```

```
[20]: {'alpha': 0.0001,
      'copy_X': True,
      'fit_intercept': True,
      'l1_ratio': 0.2,
```



```
'max_iter': 100000,
'positive': False,
'precompute': False,
'random_state': 42,
'selection': 'cyclic',
'tol': 0.0001,
'warm_start': False}
```

Choose final linear regressor model:

```
[21]: if mean_squared_error(y_test, np.exp(ridge_model.predict(X_test))) < \
      mean_squared_error(y_test, np.exp(elastic_model.predict(X_test))):
      linear_model = ridge_model
else:
      linear_model = elastic_model
```

### 1.3.2 Support Vector Regressor

```
[22]: from sklearn.svm import SVR
```

```
[23]: dict_param = {
      'C': [.0001, .001, .01, .1, 1, 10, 100, 1000, 10000],
      'epsilon': [.0001, .001, .01, .1, 1, 10, 100, 1000, 10000],
      'gamma': np.logspace(-9, 3, 13),
      'kernel': ['rbf']
    }
```

```
[24]: grid_search = GridSearchCVTrainer(name="Support Vector Regressor", model=SVR(),
    ↪ param_grid=dict_param,
    cv=5, n_jobs=5, directory='settings/doc2vec/'
    ↪+ project_name + '/')
grid_search.load_if_exists()
grid_search.fit(X_train, y_train_log)

svr_model = grid_search.best_estimator_
svr_model.fit(X_train, y_train_log)
```

There is no checkpoint file for this model.

```
100%|          | 1053/1053 [00:25<00:00, 41.64it/s]
```

```
[24]: SVR(C=100, gamma=1.0)
```

```
[25]: evaluate_model(svr_model, 'SVR model', X_test, y_test, y_logscale=True,
    ↪ save_directory='results/doc2vec/')
```

SVR model's evaluation results:

- Mean squared error: 7.2956
- Root mean squared error: 2.7010

```

- Mean absolute error:      1.7884
- R2 error:                 -0.0008
- F1 score:                 0.1931
- Precision:                0.2366
- Recall:                   0.2500
- Accuracy:                 0.2500
-----

```

```
[26]: svr_model.get_params()
```

```
[26]: {'C': 100,
      'cache_size': 200,
      'coef0': 0.0,
      'degree': 3,
      'epsilon': 0.1,
      'gamma': 1.0,
      'kernel': 'rbf',
      'max_iter': -1,
      'shrinking': True,
      'tol': 0.001,
      'verbose': False}
```

### 1.3.3 Random Forest Regressor

```
[27]: from sklearn.ensemble import RandomForestRegressor
```

```
[28]: dict_param = {
      'max_depth' : [1000, 2000, 5000],
      'min_samples_split': [25, 200, 1000],
      'min_samples_leaf': [1, 2, 3, 4],
      'max_features': [50, 100, 200],
      'n_estimators': [1024],
      'random_state': [42]
    }
```

```
[29]: grid_search = GridSearchCVTrainer(name="Random Forest Regressor",
                                       model=RandomForestRegressor(),
                                       param_grid=dict_param, cv = 5, n_jobs=-1,
                                       directory='settings/doc2vec/' + project_name_
                                       ↵+ '/')
grid_search.load_if_exists()
grid_search.fit(X_train, y_train_log)

rfr_model = grid_search.best_estimator_
rfr_model.fit(X_train, y_train_log)
```

```
0it [00:00, ?it/s]
```

```
[29]: RandomForestRegressor(max_depth=1000, max_features=50, min_samples_split=200,  
                             n_estimators=1024, random_state=42)
```

```
[30]: evaluate_model(rfr_model, 'Random Forest model', X_test, y_test,   
                    ↪y_logscale=True, save_directory='results/doc2vec/')
```

Random Forest model's evaluation results:

```
- Mean squared error:      7.4734  
- Root mean squared error: 2.7338  
- Mean absolute error:     2.1073  
- R2 error:                -0.0252  
- F1 score:                0.0025  
- Precision:               0.0013  
- Recall:                  0.0357  
- Accuracy:                0.0357
```

-----

```
[31]: rfr_model.get_params()
```

```
[31]: {'bootstrap': True,  
      'ccp_alpha': 0.0,  
      'criterion': 'squared_error',  
      'max_depth': 1000,  
      'max_features': 50,  
      'max_leaf_nodes': None,  
      'max_samples': None,  
      'min_impurity_decrease': 0.0,  
      'min_samples_leaf': 1,  
      'min_samples_split': 200,  
      'min_weight_fraction_leaf': 0.0,  
      'monotonic_cst': None,  
      'n_estimators': 1024,  
      'n_jobs': None,  
      'oob_score': False,  
      'random_state': 42,  
      'verbose': 0,  
      'warm_start': False}
```

### 1.3.4 XGBoost

```
[32]: from xgboost import XGBRegressor
```

```
[33]: dict_param = {  
      'eta' : np.linspace(0.01, 0.2, 3),  
      'gamma': np.logspace(-2, 2, 5),  
      'max_depth': np.asarray([3, 5, 7, 9]).tolist(),  
      'min_child_weight': np.logspace(-2, 2, 5),
```

```

    'subsample': np.asarray([0.5, .1]),
    'reg_alpha': np.asarray([0.0, 0.05]),
    'n_estimators': np.asarray([10, 20, 50, 100]).tolist(),
    'random_state': [42]
}

```

```

[34]: grid_search = GridSearchCVTrainer(name='XGBoost_
↳Regressor', model=XGBRegressor(), param_grid=dict_param,
                                cv = 5, n_jobs=2, directory='settings/doc2vec/
↳' + project_name + '/')
grid_search.load_if_exists()
grid_search.fit(X_train, y_train_log)

xgb_model = grid_search.best_estimator_
xgb_model.fit(X_train, y_train_log)

```

Oit [00:00, ?it/s]

```

[34]: XGBRegressor(base_score=None, booster=None, callbacks=None,
                  colsample_bylevel=None, colsample_bynode=None,
                  colsample_bytree=None, device=None, early_stopping_rounds=None,
                  enable_categorical=False, eta=0.2, eval_metric=None,
                  feature_types=None, gamma=10.0, grow_policy=None,
                  importance_type=None, interaction_constraints=None,
                  learning_rate=None, max_bin=None, max_cat_threshold=None,
                  max_cat_to_onehot=None, max_delta_step=None, max_depth=3,
                  max_leaves=None, min_child_weight=0.01, missing=nan,
                  monotone_constraints=None, multi_strategy=None, n_estimators=20,
                  n_jobs=None, num_parallel_tree=None, ...)

```

```

[35]: evaluate_model(xgb_model, 'XGBoost Regressor model', X_test, y_test,
↳y_logscale=True, save_directory='results/doc2vec/')

```

XGBoost Regressor model's evaluation results:

```

- Mean squared error:      7.5055
- Root mean squared error: 2.7396
- Mean absolute error:     2.1278
- R2 error:                -0.0296
- F1 score:                0.0025
- Precision:               0.0013
- Recall:                  0.0357
- Accuracy:                0.0357

```

-----

```

[36]: xgb_model.get_params()

```

```
[36]: {'objective': 'reg:squarederror',
      'base_score': None,
      'booster': None,
      'callbacks': None,
      'colsample_bylevel': None,
      'colsample_bynode': None,
      'colsample_bytree': None,
      'device': None,
      'early_stopping_rounds': None,
      'enable_categorical': False,
      'eval_metric': None,
      'feature_types': None,
      'gamma': 10.0,
      'grow_policy': None,
      'importance_type': None,
      'interaction_constraints': None,
      'learning_rate': None,
      'max_bin': None,
      'max_cat_threshold': None,
      'max_cat_to_onehot': None,
      'max_delta_step': None,
      'max_depth': 3,
      'max_leaves': None,
      'min_child_weight': 0.01,
      'missing': nan,
      'monotone_constraints': None,
      'multi_strategy': None,
      'n_estimators': 20,
      'n_jobs': None,
      'num_parallel_tree': None,
      'random_state': 42,
      'reg_alpha': 0.0,
      'reg_lambda': None,
      'sampling_method': None,
      'scale_pos_weight': None,
      'subsample': 0.5,
      'tree_method': None,
      'validate_parameters': None,
      'verbosity': None,
      'eta': 0.2}
```

### 1.3.5 LightGBM

```
[37]: from lightgbm import LGBMRegressor
      from sklearn.model_selection import ParameterSampler
```

```
[38]: dict_param = {
    'n_estimator': [10, 20, 50, 100, 200, 500],
    'max_depth': np.asarray([5, 7, 9, 11, 13]).tolist(),
    'num_leaves': ((np.power(2, np.asarray([5, 7, 9, 11, 13])) - 1) * (0.55 +
↪(0.65 - 0.55) * np.random.rand(5))).astype(int).tolist(),
    'min_data_in_leaf': np.linspace(100, 1000, 4).astype(int).tolist(),
    'feature_fraction': np.linspace(0.6, 1, 3),
    'bagging_fraction': np.linspace(0.6, 1, 3),
    'learning_rate': [0.01],
    'verbose': [-1],
    'random_state': [42]
}

def custom_sampler(param_grid):
    for params in ParameterSampler(param_grid, n_iter=1e9):
        range_num_leaves = ((0.5 * (2**params['max_depth'] - 1)), (0.7 *
↪(2**params['max_depth'] - 1))
        if (range_num_leaves[0] <= params['num_leaves'] <= range_num_leaves[1]):
            for key, value in params.items():
                params[key] = [value]
            yield params

[39]: grid_search = GridSearchCVTrainer(name='LightGBM Regressor',
↪model=LGBMRegressor(),
                                param_grid=list(custom_sampler(dict_param)), cv
↪= 5, n_jobs=1,
                                directory='settings/doc2vec/' + project_name +
↪ '/')
grid_search.load_if_exists()
grid_search.fit(X_train, y_train_log)

lgbmr_model = grid_search.best_estimator_
lgbmr_model.fit(X_train, y_train_log)

c:\Users\aupho\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\model_selection\_search.py:320: UserWarning: The total space of
parameters 5400 is smaller than n_iter=1000000000. Running 5400 iterations. For
exhaustive searches, use GridSearchCV.
    warnings.warn(
Oit [00:00, ?it/s]

[39]: LGBMRegressor(bagging_fraction=0.6, feature_fraction=0.6, learning_rate=0.01,
                    max_depth=5, min_data_in_leaf=400, n_estimator=10, num_leaves=19,
                    random_state=42, verbose=-1)

[40]: evaluate_model(lgbmr_model, 'LightGBM regressor model', X_test, y_test,
↪y_logscale=True, save_directory='results/doc2vec/')
```

LightGBM regressor model's evaluation results:

- Mean squared error: 7.4623
- Root mean squared error: 2.7317
- Mean absolute error: 2.0998
- R2 error: -0.0237
- F1 score: 0.0025
- Precision: 0.0013
- Recall: 0.0357
- Accuracy: 0.0357

-----

```
[41]: lgbmr_model.get_params()
```

```
[41]: {'boosting_type': 'gbdt',  
      'class_weight': None,  
      'colsample_bytree': 1.0,  
      'importance_type': 'split',  
      'learning_rate': 0.01,  
      'max_depth': 5,  
      'min_child_samples': 20,  
      'min_child_weight': 0.001,  
      'min_split_gain': 0.0,  
      'n_estimators': 100,  
      'n_jobs': None,  
      'num_leaves': 19,  
      'objective': None,  
      'random_state': 42,  
      'reg_alpha': 0.0,  
      'reg_lambda': 0.0,  
      'subsample': 1.0,  
      'subsample_for_bin': 200000,  
      'subsample_freq': 0,  
      'verbose': -1,  
      'n_estimator': 10,  
      'min_data_in_leaf': 400,  
      'feature_fraction': 0.6,  
      'bagging_fraction': 0.6}
```

### 1.3.6 Stacked model:

```
[42]: from mlxtend.regressor import StackingCVRegressor
```

Define component models:

```
[43]: trained_models = [linear_model, svr_model, rfr_model, xgb_model, lgbmr_model]
```

Define blended model:

```
[44]: stack_gen = StackingCVRegressor(regressors=tuple(trained_models),
                                     meta_regressor=trained_models[np.
                                     ↪argmin([mean_squared_error(np.exp(model.predict(X_test)), y_test) for model_
                                     ↪in trained_models])),
                                     use_features_in_secondary=True, n_jobs=-1,
                                     ↪random_state=42)
print(stack_gen)
```

```
StackingCVRegressor(meta_regressor=Ridge(alpha=0.01, random_state=42),
                    n_jobs=-1, random_state=42,
                    regressors=(Ridge(alpha=0.01, random_state=42),
                                SVR(C=100, gamma=1.0),
                                RandomForestRegressor(max_depth=1000,
                                                        max_features=50,
                                                        min_samples_split=200,
                                                        n_estimators=1024,
                                                        random_state=42),
                                XGBRegressor(base_score=None, booster=None,
                                              callbacks=None,
                                              colsample_bylevel=None,
                                              max_delta_step=None, max_depth=3,
                                              max_leaves=None,
                                              min_child_weight=0.01, missing=nan,
                                              monotone_constraints=None,
                                              multi_strategy=None,
                                              n_estimators=20, n_jobs=None,
                                              num_parallel_tree=None, ...),
                                LGBMRegressor(bagging_fraction=0.6,
                                              feature_fraction=0.6,
                                              learning_rate=0.01, max_depth=5,
                                              min_data_in_leaf=400,
                                              n_estimator=10, num_leaves=19,
                                              random_state=42, verbose=-1)),
                    use_features_in_secondary=True)
```

```
[45]: stack_gen.fit(X_train, y_train_log)
```

```
[45]: StackingCVRegressor(meta_regressor=Ridge(alpha=0.01, random_state=42),
                          n_jobs=-1, random_state=42,
                          regressors=(Ridge(alpha=0.01, random_state=42),
                                      SVR(C=100, gamma=1.0),
                                      RandomForestRegressor(max_depth=1000,
                                                            max_features=50,
                                                            min_samples_split=200,
                                                            n_estimators=1024,
                                                            random_state=42),
                                      XGBRegressor(base_score=None, booster=None,
```



```

callbacks=None,
colsample_bylevel=None,
max_delta_step=None, max_depth=3,
max_leaves=None,
min_child_weight=0.01, missing=nan,
monotone_constraints=None,
multi_strategy=None,
n_estimators=20, n_jobs=None,
num_parallel_tree=None, ...),
LGBMRegressor(bagging_fraction=0.6,
               feature_fraction=0.6,
               learning_rate=0.01, max_depth=5,
               min_data_in_leaf=400,
               n_estimator=10, num_leaves=19,
               random_state=42, verbose=-1)),
               use_features_in_secondary=True)

```

```

[46]: evaluate_model(stack_gen, 'Stacking model', X_test, y_test, y_logscale=True,
                    ↪save_directory='results/doc2vec/')

```

Stacking model's evaluation results:

```

- Mean squared error:      6.7010
- Root mean squared error: 2.5886
- Mean absolute error:     1.7366
- R2 error:                0.0807
- F1 score:                0.2243
- Precision:               0.2887
- Recall:                  0.2500
- Accuracy:                0.2500

```

---

```

[47]: stack_gen.get_params()

```

```

[47]: {'cv': 5,
      'meta_regressor__alpha': 0.01,
      'meta_regressor__copy_X': True,
      'meta_regressor__fit_intercept': True,
      'meta_regressor__max_iter': None,
      'meta_regressor__positive': False,
      'meta_regressor__random_state': 42,
      'meta_regressor__solver': 'auto',
      'meta_regressor__tol': 0.0001,
      'meta_regressor': Ridge(alpha=0.01, random_state=42),
      'multi_output': False,
      'n_jobs': -1,
      'pre_dispatch': '2*n_jobs',
      'random_state': 42,

```

```

'refit': True,
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                        n_estimators=1024, random_state=42),
XGBRegressor(base_score=None, booster=None, callbacks=None,
              colsample_bylevel=None, colsample_bynode=None,
              colsample_bytree=None, device=None, early_stopping_rounds=None,
              enable_categorical=False, eta=0.2, eval_metric=None,
              feature_types=None, gamma=10.0, grow_policy=None,
              importance_type=None, interaction_constraints=None,
              learning_rate=None, max_bin=None, max_cat_threshold=None,
              max_cat_to_onehot=None, max_delta_step=None, max_depth=3,
              max_leaves=None, min_child_weight=0.01, missing=nan,
              monotone_constraints=None, multi_strategy=None, n_estimators=20,
              n_jobs=None, num_parallel_tree=None, ...),
LGBMRegressor(bagging_fraction=0.6, feature_fraction=0.6, learning_rate=0.01,
              max_depth=5, min_data_in_leaf=400, n_estimator=10,
num_leaves=19,
              random_state=42, verbose=-1)),
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'use_features_in_secondary': True,
'verbose': 0,
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min_samples_split=200,
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'xgbregressor': XGBRegressor(base_score=None, booster=None, callbacks=None,
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                             colsample_bytree=None, device=None, early_stopping_rounds=None,
                             enable_categorical=False, eta=0.2, eval_metric=None,
                             feature_types=None, gamma=10.0, grow_policy=None,
                             importance_type=None, interaction_constraints=None,
                             learning_rate=None, max_bin=None, max_cat_threshold=None,
                             max_cat_to_onehot=None, max_delta_step=None, max_depth=3,
                             max_leaves=None, min_child_weight=0.01, missing=nan,
                             monotone_constraints=None, multi_strategy=None, n_estimators=20,
                             n_jobs=None, num_parallel_tree=None, ...),
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learning_rate=0.01,
                             max_depth=5, min_data_in_leaf=400, n_estimator=10, num_leaves=19,
                             random_state=42, verbose=-1),
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'ridge__copy_X': True,
'ridge__fit_intercept': True,

```

```

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'ridge__tol': 0.0001,
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'svr__verbose': False,
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'randomforestregressor__warm_start': False,
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'xgbregressor__base_score': None,
'xgbregressor__booster': None,
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'xgbregressor__colsample_bytree': None,
'xgbregressor__device': None,
'xgbregressor__early_stopping_rounds': None,
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'xgbregressor__eval_metric': None,
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```

```

'xgbregressor__grow_policy': None,
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'xgbregressor__max_leaves': None,
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'xgbregressor__monotone_constraints': None,
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'xgbregressor__validate_parameters': None,
'xgbregressor__verbosity': None,
'xgbregressor__eta': 0.2,
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'lgbmregressor__class_weight': None,
'lgbmregressor__colsample_bytree': 1.0,
'lgbmregressor__importance_type': 'split',
'lgbmregressor__learning_rate': 0.01,
'lgbmregressor__max_depth': 5,
'lgbmregressor__min_child_samples': 20,
'lgbmregressor__min_child_weight': 0.001,
'lgbmregressor__min_split_gain': 0.0,
'lgbmregressor__n_estimators': 100,
'lgbmregressor__n_jobs': None,
'lgbmregressor__num_leaves': 19,
'lgbmregressor__objective': None,
'lgbmregressor__random_state': 42,
'lgbmregressor__reg_alpha': 0.0,
'lgbmregressor__reg_lambda': 0.0,
'lgbmregressor__subsample': 1.0,
'lgbmregressor__subsample_for_bin': 200000,
'lgbmregressor__subsample_freq': 0,
'lgbmregressor__verbose': -1,

```

```
'lgbmregressor__n_estimator': 10,  
'lgbmregressor__min_data_in_leaf': 400,  
'lgbmregressor__feature_fraction': 0.6,  
'lgbmregressor__bagging_fraction': 0.6}
```